REPRODUCTIVE BIOLOGY OF THE TUI CHUB, *GILA BICOLOR*, IN PYRAMID LAKE, NEVADA

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ABSTRACT.— Sex ratios for tui chubs (*Gila bicolor*), obtained from a sample of 3,384 fish, deviated significantly from the expected 1:1 ratio (chi-square, P<0.05). Spawning occurred from June to August, with estimated fecundities ranging from 6,110 to 68,933 ova. Females spawned after attaining a maximum (average) gonadal somatic index (GSI—percent gonad weight/total body weight) of 9.1 percent and between surface water temperatures of 15.5 to 22.2 C. Males reached sexual maturity at age two, with most females maturing at age three. Consistent increases in fecundity were apparent with increasing length, weight, and age. Linear regressions between fork length and fecundity and weight and fecundity were highly significant (P<0.05).

The tui chub (*Gila bicolor*) is a cyprinid found in the drainage systems on both sides of the Sierra Nevada, from the San Joaquin and Lahontan systems north to the lakes of southern Oregon and the Columbia River (LaRivers 1962). In Pyramid Lake *G. bicolor* comprises nearly 89 percent of the net catch and represents the main forage base for the Lahontan cutthroat trout (*Salmo clarki henshawi*). Tui chubs also represent a principal component in the bioenergetics of the Pyramid Lake ecosystem.

The present study is a part of the total ecological research and fish life history studies being conducted on Pyramid Lake. Those aspects of the reproductive biology that were studied included: sex ratios, total and by month; changes in fish catch rates and sex ratios; development of the ova and ovaries in relation to the spawning season; age and size at sexual maturity; and number of ova in relation to fish length and weight.

METHODS

Tui chubs were collected monthly from November 1975 through June 1977 in Pyramid Lake, Nevada. Two gear types were utilized in the collection of chubs: variable-mesh bottom-set gill nets and fyke nets. Females selected for fecundity studies were collected during June and July of 1976 and 1977. These months were selected to ensure collection of ripe females.

Ovaries were removed from 23 tui chubs for fecundity determination. Each pair of ovaries was weighed to ± 1 mg, and 10 ovum diameters per ovary were measured to the nearest 0.1 mm with an ocular micrometer. The fork length of each fish was measured to the nearest millimeter, and each fish was weighed to the nearest gram. All fecundity determinations were made with fresh ovaries.

Fecundity was estimated by the gravimetric method (Jester 1973; June 1971). Three replicate subsamples of approximately 0.5 g were taken from each ovary, weighed to the nearest 1 mg, and preserved for later counting. Fecundity was then calculated by direct proportion per ovary.

Sex ratios were obtained through internal examination of 3,384 fish. Age groups were assigned by the scale method and length frequency histograms. Linear and $\log_{10}$ regressions between fecundity and fork length and fecundity and weight were used to examine the relationships between these variables.

DISCUSSION

Sex ratios for tui chubs were obtained from a sample of 3,384 fish sampled from

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TABLE 1. Monthly sex ratios of adult tui chubs sampled from November 1975 through February 1977 in Pyramid Lake, Nevada.

	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F
Males	60	74	52	14	76	96	126	462	93	95	79	87	56	31	92	46
Females	91	104	84	51	171	179	134	289	106	75	76	96	100	80	155	54
Ratio M:F	1:1.52	1:1.41	1:1.62	1:3.64	1:2.25	1:1.86	1:1.06	1.6:1	1:1.14	1.27:1	1.04:1	1:1.1	1:1.78	1:2.58	1:1.68	1:1.17

November 1975 through February 1977. The 1:1.20 ratio, 1,539 males to 1,845 females, represents a significant deviation from the expected 1:1 ratio (chi-square, $P<0.05$). Sex ratios by month (Table 1) present interesting fluctuations. Substantial deviations in sex ratios for duplicated months (December and February) are readily apparent and heavily favor the females. This is probably the result of sampling bias. The important trend takes place from April through August, which coincides with the spawning season. In April, the ratio of males to females is almost 1:2. This changes dramatically in May to 1:1.06, in June to 1.6:1, to 1:1.14 in July, and 1.27:1 in August. Deviations in sex ratios in May and June could be attributed to the movement of males to spawning sites. Of 262 tui chubs sexed from one inshore bottom gill net in early June 1976, 86 percent were males. Data collected from Walker Lake, Nevada (Cooper, personal communication), in mid-June parallel this result (85 percent of the tui chubs sampled in 5–7 m of water were males).

Increases in the percentage of males sampled from April through June are accompanied by an increased bottom inshore catch of tui chubs (Fig. 1). Although monthly sex ratios were shown to be variable (Table 1), they usually favored the females. From May to June, the percent of males increased from 49 to 62 percent, indicating a prespawning movement of males inshore. Catch rates also increased dramatically in May, and steadily rose in June. An influx of females in July, corresponding to peak spawning, decreased the percentage of males to 46 percent. Increased activity, and thus increased catches, for both sexes, also parallel major periods of zooplankton standing crops, macroinvertebrate abundances, increasing water temperatures, feeding habits, and growth rates. The overall catch rate inshore in August decreased by 71 percent from the bottom inshore average numbers of June and July. This corresponds with the completion of the spawning season and must result from differential behavior and distribution of mature fish related to spawning.

Constant increases in the average female gonadal somatic index (GSI—percent gonad weight/total body weight) were noted from February through May, with a major increase of 3.8 percent in June (Fig. 2). This period of major germinal growth (May to June) took place after the major increase in
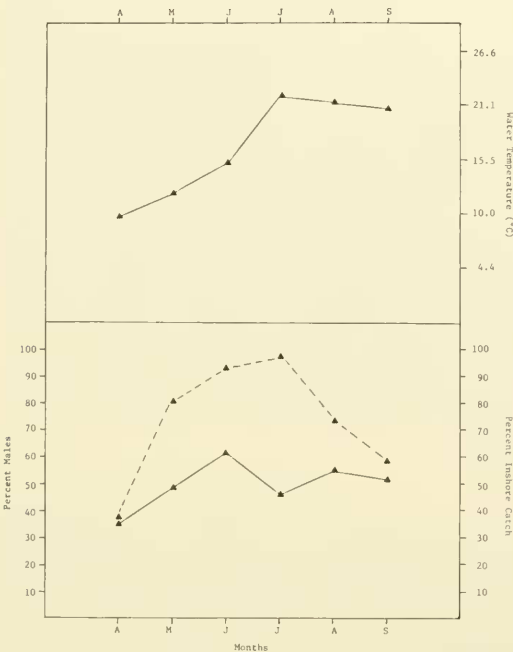

Fig. 1. Monthly changes in sex ratios (solid line) and inshore catch rates (dash line) of tui chubs in Pyramid Lake in 1976. Water temperatures are monthly inshore surface averages.

somatic growth (fork length) in fall and winter. Consequently, tui chubs foraged very actively to support both germinal and somatic increases. Females attained a maximum average GSI in June of 9.2 percent as inshore water temperatures approached 15.5 C. Zooplankton standing crops and macroinvertebrate abundances were both high during this period, thus providing ample food sources. Spawning occurred from June to August, with peak spawning in July when the GSI dropped from 7.3 percent to 1.5 percent in August. Inshore water temperatures in June were 15.5 C and in July were 22.2 C. In Eagle Lake, California, tui chubs spawned when water temperatures reached about 15.5 C (Kimsey 1954). Spawning activity of Mojave chubs, *Gila*

mohavensis, in Soda Lake, California, peaked in mid-March at water temperatures of 18 C (Vicker 1973).

LaRivers (1962) states that tui chubs congregate along the shoreline during the spawning season. Bottom gill net catches reveal that almost 97 percent of the tui chubs were inshore in July. This corresponds with the time of peak spawning. Although no spawning activity or spawn was observed during this study, chubs have been seen spawning in shallow water in Pyramid Lake (Galat, pers. comm.). Initiation of sampling during the summer of 1977 to determine vertical distribution patterns suggested the possibility of two separate chub populations: a fine-rakered limnetic population and a coarse-rakered population. The tax-
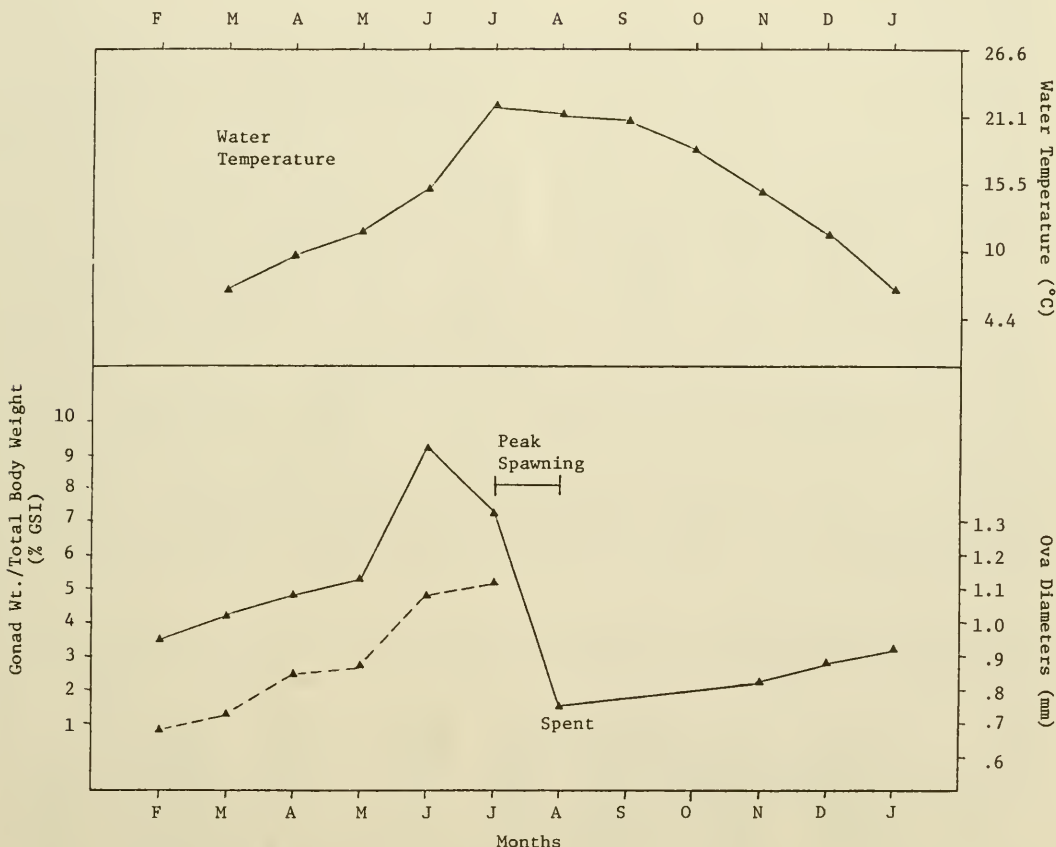

Fig 2. Comparison of monthly tui chub gonadal somatic index values (solid line) with ova diameters (dash line). Water temperatures are monthly inshore surface averages.

onomic controversy concerning the tui chub is well documented (Hubbs and Miller 1943, Hubbs et al. 1974, Kimsey 1954, LaRivers and Trelease 1952, LaRivers 1962). It is believed that the spawning discussion includes the bottom-dwelling chubs, but the paucity of data on pelagic chubs precludes any conclusion that they also spawn inshore. Varley and Livesay (1976) observed movement of prespawning and spawning populations of Utah chub, *Gila atraria*, in Flaming Gorge Reservoir, Utah-Wyoming. In the summer these chubs move onshore into littoral areas from mid to late afternoon, apparently to spawn, and then move lakeward into pelagic areas by early morning hours. Diel distribution patterns of Utah chubs in Fish Lake, Utah (Gaufin 1964), also indicate concentrations of chubs in littoral areas during the night.

In Pyramid Lake, female tui chubs are sexually mature at two years of age, and all are mature by age three; the majority of males also mature at two and all by three. After attaining sexual maturity, chubs ripen and spawn every year. The oldest mature female sampled was of age group VII, and the oldest mature male was of age group IV. Upon attaining maturity, Utah chub males showed a higher rate of mortality as age group V, and older females outnumbered males almost 10 to 1 (Varley and Livesay 1976).

Age group III chubs comprised the majority of females sampled for fecundity studies (Table 2). Three-year-old females averaged 232 mm in fork length and 15,135 ova per female. Age group IV females averaged 277 mm in fork length and 31,622 ova per female. One age group V female was 307

mm in fork length and contained an estimated 50,032 ova. One age group VII female was 378 mm long and contained an estimated 68,933 ova. Estimated egg production per female ranged from 6,110–68,933 eggs and averaged 23,292 ova. Olson (1959) found the average number of eggs for Utah chubs from Scofield Reservoir, Utah, to be 25,282 ova per female. In Hebgen Lake, Montana, Graham(1955) found Utah chub fecundities to average 40,750 eggs per female, although his sample size of n=7 was small. Estimated fecundities for six Mojave chubs averaged 12,687 ova per female (Vicker 1973). Tui chubs exhibited consistent increases in fecundity, with increases in length, weight, and age (r values; $P < 0.05$). Ova diameters, from green ovaries, ranged from 1.1–1.7 mm and averaged 1.3 mm for all year classes. Kimsey (1954) described newly extruded tui chub eggs as being 1.5–1.9 mm in diameter, and Harry (1951) stated that freshly stripped tui chub eggs were 1.8–2.0 mm in diameter.

The linear relationship between fork length and fecundity (Fig. 3) was highly significant (F = 94.8; $P < 0.05$). A significant ($P < 0.05$) correlation coefficient exists between fork length and fecundity, because 82 percent of the variation in fecundity was accounted for by variation in length. The positive linear relationship between weight and fecundity was also highly significant (F = 211.2; $P < 0.05$), demonstrating an increase in fecundity with increasing weight (Fig. 4). A significant ($P < 0.05$) correlation coefficient exists, and 91 percent of the variation in fecundity was explained by variation in weight. Both fork length and fecundity and weight and fecundity had

TABLE 2. Average lengths, weights, ovum diameters, and fecundities, per age group, for 23 tui chub from Pyramid Lake, Nevada, 1976 and 1977.

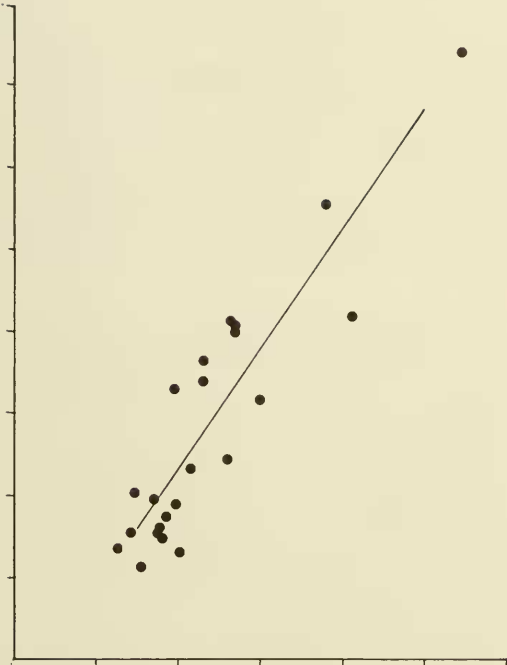| Number of Tui Chub	Age Group	Range in Fork Length (mm)	Average Fork Length (mm)	Range in Weight (grams)	Average Weight (grams)	Range in Egg Diameter (mm)	Average Diameter (mm)	Range in Number of eggs	Average Number
15	III	210–252	232	96–238	154	1.1–1.5	1.3	6,110–31,432	15,135
6	IV	263–323	277	196–410	317	1.2–1.4	1.3	19,307–36,993	31,622
1	V	—	307	—	444	—	1.3	—	50,032
—	VI	—	—	—	—	—	—	—	—
1	VII	—	378	—	661	—	1.35	—	68,933

Fig. 3. The relationship between fork length and fecundity for 23 tui chubs from Pyramid Lake, Nevada, 1976 and 1977.
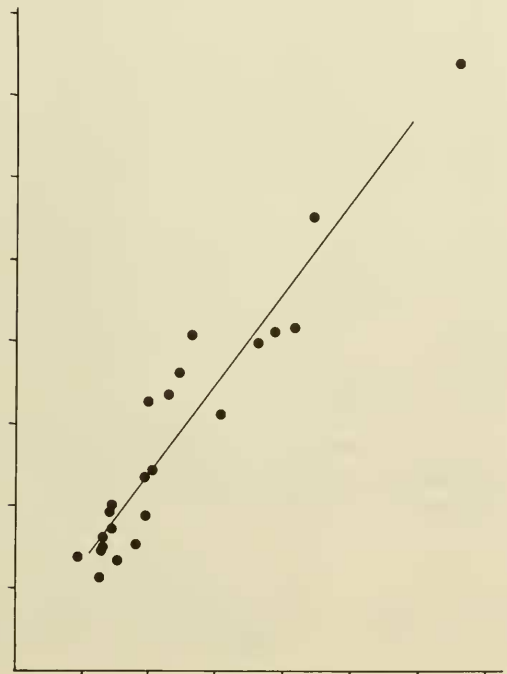

Fig. 4. The relationship between weight and fecundity for 23 tui chubs from Pyramid Lake, Nevada, 1976 and 1977.

significant $\log_{10}$ fits but were best described by a linear fit.

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